Counter-Gravity Casting of IN625 Alloy in Thin-walled Investment Shell Moulds

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Abstract: IN625 alloy is used for high temperature applications. The gravity pouring and counter-gravity pouring methods were employed to cast IN625 alloy in the investment shell moulds. The grain size was measured based ASTM E1382 standard. The counter-gravity pouring gave fine grain structure and better mechanical properties than those of the castings fabricated by gravity pouring method.

Keywords: Investment casting, IN625 alloy, colloidal silica binder, zirconia, counter-gravity pouring, gravity pouring, grain size.

1. INTRODUCTION

Inconel alloys are austenite nickel-chromium-based superalloys. They are oxidation and corrosion resistant materials well suited for service in extreme environments subjected to pressure and heat. Strength of IN625 is derived from the stiffening effect of molybdenum and niobium on its nickel-chromium matrix; thus precipitation hardening treatments are not required. This combination of elements also is responsible for superior resistance to a wide range of corrosive environments of unusual severity as well as to high-temperature effects such as oxidation and carburization [1].

In the counter-gravity process, metal is drawn up into the mold by vacuum (figure 1b). After a brief hold time, allowing the parts and a portion of the gate to solidify, the vacuum is released and the metal in the central sprue flows back into the melt. Only a short, easily machined gate stub remains on the casting.

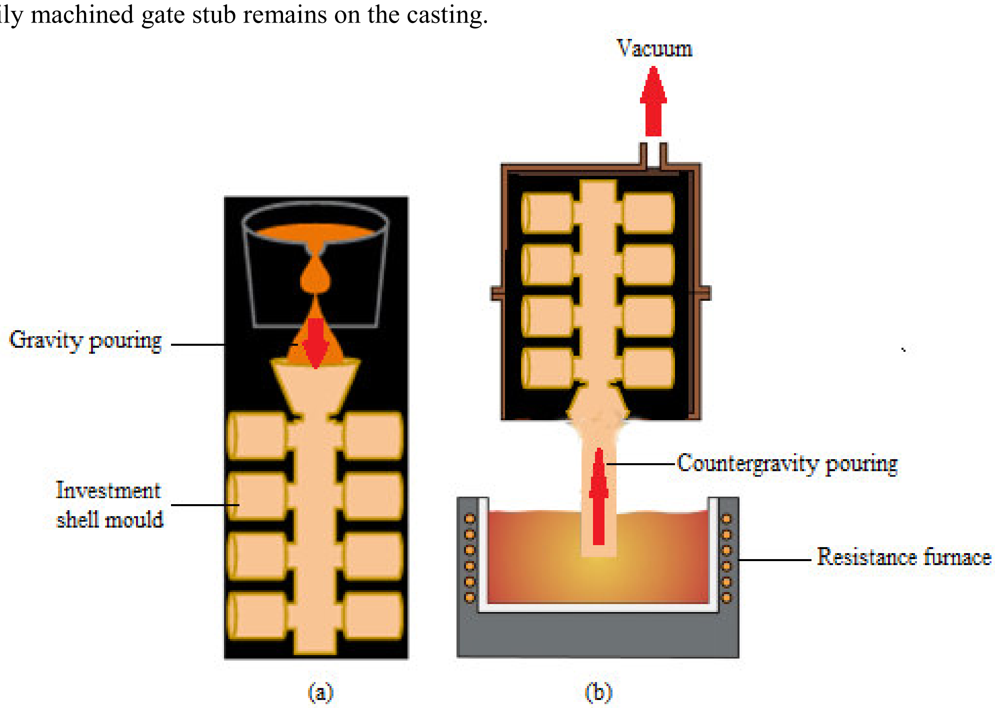


Figure 1: Pouring of investment shell moulds: (a) gravity and (b) counter-gravity.

The objectives of present work were as follows:

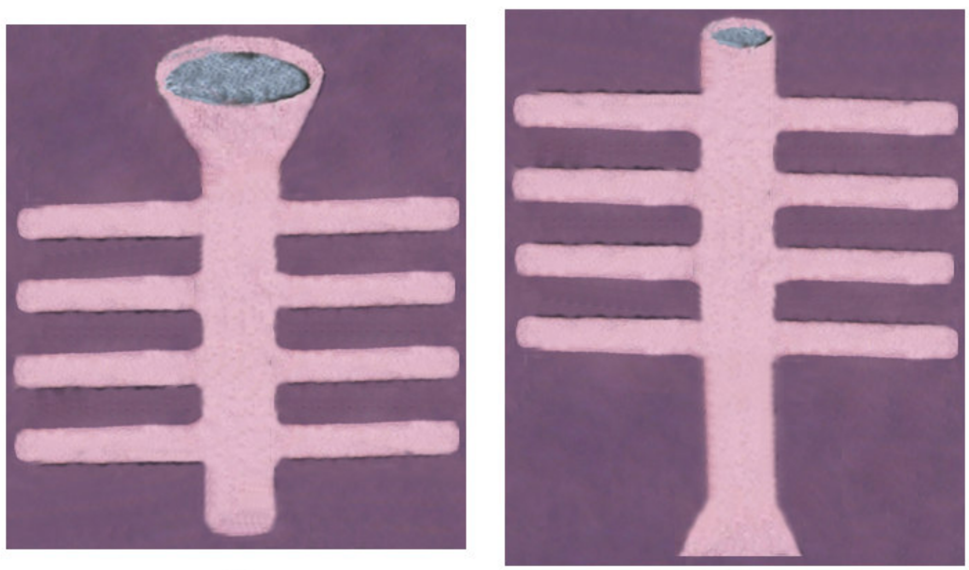
- to cast IN625 alloy in thin-walled investment shell moulds under gravity pouring (figure 1a) and counter-gravity pouring (figure 1b) techniques, and
- to compare the microstructures and mechanical properties of gravity and counter-gravity cast IN625 samples.

2. MATERIALS METHODS

The chemical composition of IN625 alloy is given in table 1. In the present work, the colloidal silica binder was used to fabricate the ceramic shell moulds from zirconia and graphite as reinforced filler materials. The silica content in the colloidal silica binder was 30%. Two grades (primary and backup sands) of stuccoing sand were employed in the present investigation. Finer grade silica sand having AFS grain fineness number 120 was employed for primary coats. This is synthetic sand. This sand was used for first two coats, called prime coats to get good surface finish and every detail of the wax pattern. Coarser grade sand having AFS grain fineness number 42 was employed for back up coats. This is river sand. The backup sand was employed to develop more thickness to the shell walls with minimum coats. The thickness of shell moulds were 12 mm. After all coats, the shells were air dried for 24 hours. Two shells of each treatment were made as shown in figure 2. The IN625 alloy was melted in an induction furnace under vacuum [2-22].

Table 1: Chemical composition of Ni-base super alloy

Element	Ni	Cr	Co	Mo	Fe	Nb	C	Mn	Si	P	S	Al	Ti	Co
%wt	58.0 min	22.0	15	9.0	5.0	6.0	0.1 max	0.5 max	0.5 max	0.015 max	0.01 max	0.4 max	0.4 max	1.0 max



(a) (b)

Figure 2: Investment shell moulds: (a) gravity poured and (b) counter-gravity poured.

The liquid alloy was gravity poured under vacuum into the pre-heated investment shell moulds. Also, the investment shell moulds were counter-gravity poured. In the counter-gravity casting process, as soon as the molten alloy is ready to be cast, a preheated investment shell mould was placed on the bottom opening of a mould chamber. A preheated investment shell mould was transferred into the chamber and placed on top of the ceramic tube. Support media is packed around the preheated shell mould and the chamber containing the shell mould is transferred to the melting furnace. The shell mould at the bottom of the chamber is then inserted into the argon atmosphere above the molten alloy. Argon was drawn into to the shell mould chamber by creating a vacuum in the shell mould. This action essentially displaced air in the shell mold cavity through the semiporous mould with argon. The mould was then inserted deep into the molten alloy and the vacuum in the shell mould cavity was increased at a controlled rate, enabling the mould filling. The level of vacuum in the mould cavity was 1/3 of an atmosphere to fill the mold in 5 seconds.

The shell moulds were knocked off by hand hammer after solidification of the molten. The castings were cleaned with soft brush and visually inspected for pins and projections.

The average grain size was measured using the linear intercept method. As per the recommendation of ASTM E1382, four evenly spaced directions (0°, 45°, 90°, 135°) were used (figure 3).

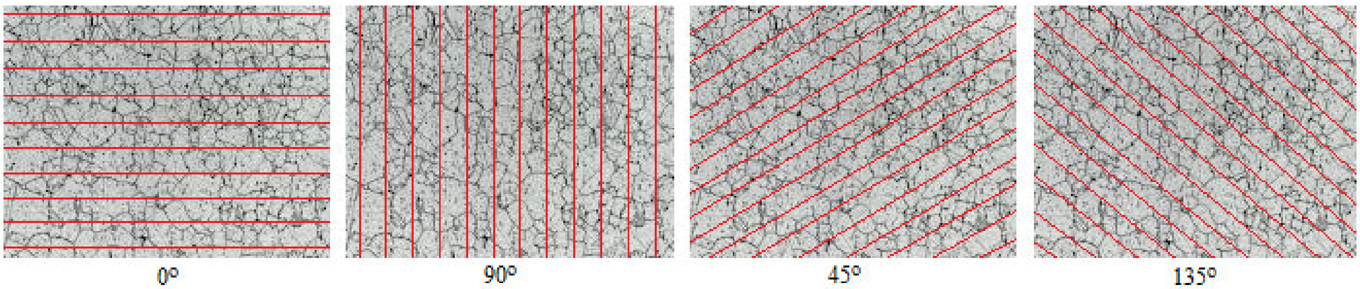


Figure 3: Grain size measurement.

3. RESULTS AND DISCUSSION

With gravity pouring, the microstructure of IN625 alloy reveals coarse gain structure; while it is fine grain structure through counter-gravity technique as seen from figure 4. The average grain size of IN625 alloy under gravity pouring (GP) is 5.56 µm. The average grain size of IN625 alloy under counter-gravity pouring (CGP) is 3.70 µm (figure 5).

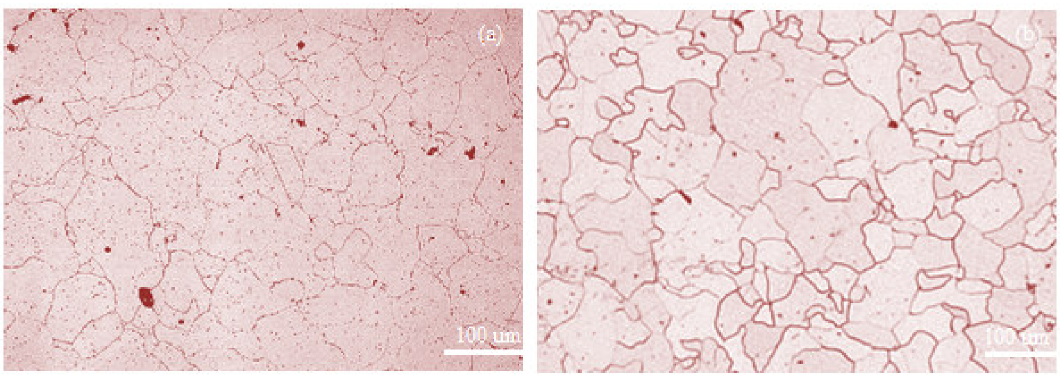


Figure 4: Optical microstructures of IN625 alloy: gravity poured and (b) counter-gravity poured.

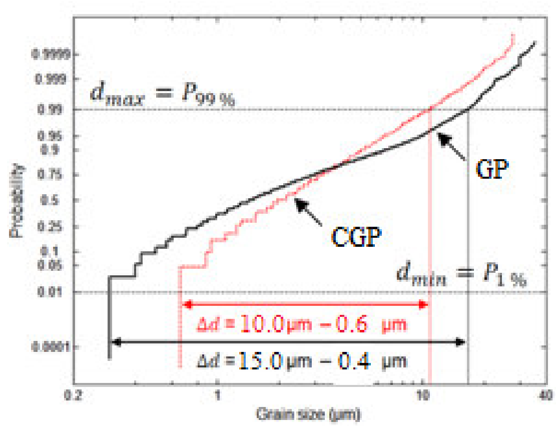


Figure 5: Log-normal probability plot.

The mechanical properties of IN625 alloy is given in table 2. The mechanical properties of IN625 alloy cast with counter-gravity pouring has superior properties than those of the same alloy cast with gravity pouring. This might be attributed to the grain size and porosity in the castings as observed in figure 4.

Table 2: Mechanical properties of IN625 alloy

S.No.	Property	Gravity pouring	Counter-gravity pouring
1	Ultimate tensile strength, MPa	910	894
2	Yield strength at 0.2%, MPa	464	458
3	Elongation, %	46	44
4	Rockwell hardness	B98	B94

4. CONCLUSIONS

The counter-gravity pouring of IN625 alloy in investment shell moulds has yielded fine grain structure in the castings. Also, the mechanical properties of IN 625 alloy are superior with counter-gravity pouring.

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